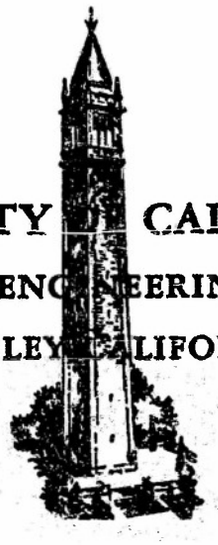

UNIVERSITY OF CALIFORNIA
INSTITUTE OF ENGINEERING RESEARCH
BERKELEY CALIFORNIA

SPECTRAL REFLECTIVITY OF CERTAIN MINERALS AND SIMILAR INORGANIC MATERIALS

Contract No. DA-11-190-ENG-3
8-66-02-001

SNOW ICE AND PERMAFROST
RESEARCH ESTABLISHMENT
Corps of Engineers
U. S. Army
1215 Washington Ave.
Wilmette, Illinois

SERIES NO. 62

ISSUE NO. 4

DATE January 29, 1954

SPECTRAL REFLECTIVITY OF CERTAIN MINERALS AND SIMILAR INORGANIC MATERIALS

FACULTY INVESTIGATORS

J. T. Gier
R. V. Dunkle

PERSONNEL

A. J. Test	Coordinator
J. T. Bevans	Project Engineer
J. Fogle	Engineering Aid
G. Lee	Grad. Res. Engr.
M. Iwama	Engineering Aid
A. Etemad	Grad. Res. Engr.
W. Pippin	Engineering Aid

SPECTRAL REFLECTIVITY OF CERTAIN MINERALS AND SIMILAR INORGANIC MATERIALS

Introduction

One of the objectives of the research investigation sponsored by the Snow, Ice and Permafrost Research Establishment of the U. S. Army Corps of Engineers under Contract DA-11-190-ENG-3, is the measurement of the spectral reflectivity of various materials. Of particular interest to investigators in the problems of radiative exchange and over-all heat balances of the natural environment, is the emission characteristics of the different constituents of what is loosely termed the earth. Thus, the spectral reflectivity characteristics of minerals and associated materials is of prime importance. The following report is the result of a preliminary investigation of the spectral reflectivity of certain minerals and other similar materials.

The spectral reflection of minerals is characterized by region(s) of high refleotion known as "rest-strahlen" or residual ray reflection. Such materials as quartz, fluorspar, calcite, etc. have been investigated extensively by many investigators for the purpose of obtaining information regarding the nature of absorption and reflection. The selective reflections have also been used to isolate narrow bands of infra-red energy for use in the laboratory. The present work was not concerned with such applications but was directed toward determination of the influence of these bands upon the emission characteristics and the energy balance of the natural surrounds.

As an illustration of this problem, the characteristics of quartz may be chosen. Crystalline quartz reflects selectively in the region of 8.5 microns. The peak of a Planckian radiator at 90°F occurs at 8.5 microns and since the energy emitted is a product of the spectral emissivity ($e_\lambda = 1 - r_\lambda$) and the Planckian energy distribution, the effect of this selective reflection is to reduce the energy emitted. Other materials have different "rest-strahlen" bands and hence a soil consisting predominantly of one material may have a different equilibrium temperature (for a particular radiation) than another type of soil.

The problem of determination of these selective reflections is complicated by the effects of the physical form of the material. Powdered or granular materials will differ from the solid, planar form. In addition, the size of the particles becomes quite important as the size approaches dimensions of the order of the wavelength of the energy under consideration.

The results reported herein are those of the preliminary investigation. A total of 24 different materials were tested using different experimental techniques. The results are contained in the tabulations of the 41 measurements reported.

Experimental Method

The reflectivities were determined with the heated cavity reflectometer. This instrument has been described in full detail in the Progress Report dated June 27, 1953 (Gier and Dunkle, 1953). Briefly, the energy reflected from a water cooled sample inserted in an ideal radiator is passed through a Perkin-Elmer Infra-red Spectrometer. This measurement is compared to that obtained from the ideal radiator and the ratio of the two measurements is the absolute spectral reflectivity.

The preparation of the sample was of prime importance, as noted previously. A sample material was ground into a powder and dusted upon an aluminum disk covered with either black paint or sodium silicate. The paint or the sodium silicate acted as an adhesive between the aluminum and the sample. No effort was made to obtain a particular particle size or range of sizes. In the initial stages of the investigation, the development of methods and techniques of preparation of samples was emphasized. An effort was made to grind the samples in such a manner as to obtain a variety of particle sizes. Qualitatively, this was believed to be more representative of the natural material. The only sample for which a plane surface could be obtained was mica. This sample was prepared by splitting a thicker mica sheet until a very thin section was obtained. This was then mounted in the sample holder without any adhesive material.

The adhesive material used also furnished the background or reflecting surface for transmittant samples. Ideally, such a material should be opaque and have a constant reflectivity for all wavelengths. The value of the reflectivity should be very nearly zero, and the thickness necessary to obtain the preceeding conditions should be a maximum of 0.002 to 0.003 inches. This latter condition is necessitated by the problem of cooling of the sample surface. Black paint was satisfactory in most respects, but too great a thickness was required to insure these conditions. Sodium silicate was better than black paint but unfortunately, this material has a "rest-strahlen" reflection in the region of 10 microns. Consequently, to insure reliable results, a sample that indicated a reflection in the same region as the sodium silicate was also measured using black paint. True reflection then could be separated from transmission through the sample combined with reflection from the sodium silicate.

The sample minerals in most instances were obtained from a shop dealing in mineral specimens for collectors and hence were not chemically prepared materials but were as taken from the ground.

Discussion of Results

The results obtained may be compared to those of other investigators. Wood (Wood, page 518, 1934) lists values of the wavelength of maximum reflection for a few materials:

	WAVELENGTH (MICRONS)	
	Wood	Present Investigation
Quartz	8.5	9.0
Calcite	6.76	6.62
Fluorite	2.4	2.20

The differences are attributed to the use of powdered material in the present investigation whereas the results given by Wood are for solid samples. In addition, any impurities would materially affect the results and could possibly distort the position of the maxima. In view of these facts the comparison is

quite favorable.

The magnitudes of the reflection from samples on black paint and on sodium silicate, differed in some cases by appreciable amounts. This is due partly to sample materials varying in impurities. A major source of this discrepancy was the nonuniformity of sample preparation. It was not possible to duplicate two samples as to thickness, particle size, etc., with the only difference being the background adhesive. If the results presented here were to be used for calculations of emissivities or reflectivities, the average of the two sets of data could be used to obtain an approximate answer.

An interesting set of data, is that presented for dirt (Table 15, 16, 17 and 18). The material used was that reported in "The Snow Emissivity Meter And Its Use In Evaluating The Emissivity Of Ice, Frozen Ground And Other Materials" (Gier and Dunkle, 1953). The value of the emissivity for the dirt was reported as 0.94 and 0.95. The spectral data may be seen to compare quite favorably at the wavelengths which would be involved (8 microns and greater).

Mica was used to illustrate the difference between a powdered sample and the solid form. The peak of the "rest-strahlen" reflection occured at 9.62 microns for both the solid and flake form, but the value of this maximum differed, 63.5 percent vs. 45 percent respectively. The reflection at other wavelengths also differed as a result of the effect of transmission combined with the reflection differences between the sample forms.

The results presented are for a limited number of materials and were obtained with the heated cavity reflectometer. The sample technique which is required with this instrument introduced the effect of the adhesive. This extraneous influence was believed to have been eliminated as may be seen by comparison of the results obtained with two different adhesives with the same sample material. Unfortunately, the sample technique was also subject to variation between two samples of the same material by virtue of the powdering and dusting procedure. The difficulties noted will be eliminated by use of the

paraboloid reflectometer described in the Progress Report for the year June 27, 1952 to June 27, 1953 (Gier and Dunkle, 1953). With this device, solid and powdered samples may be used with greater control of sample composition and form.

The results reported are of interest when compared to the transmission data published by J. M. Hunt et al. (J. M. Hunt, et al., 1950). Transmission was measured by depositing samples of known particle size upon rock salt windows. This information has been suggested as a means of analysis of complex inorganic mixtures (J. M. Hunt and D. S. Turner, 1953).

Conclusions

1. An acceptable technique of sampling has been developed for measurement of the spectral reflection of powdered minerals.

2. The spectral reflectivity of certain minerals indicates a nonuniformity of emissivity which would alter the equilibrium temperatures of these materials when exposed to the natural environment.

3. This type of measurement will be extended in scope and nature with the completion of the paraboloid reflectometer now under construction.

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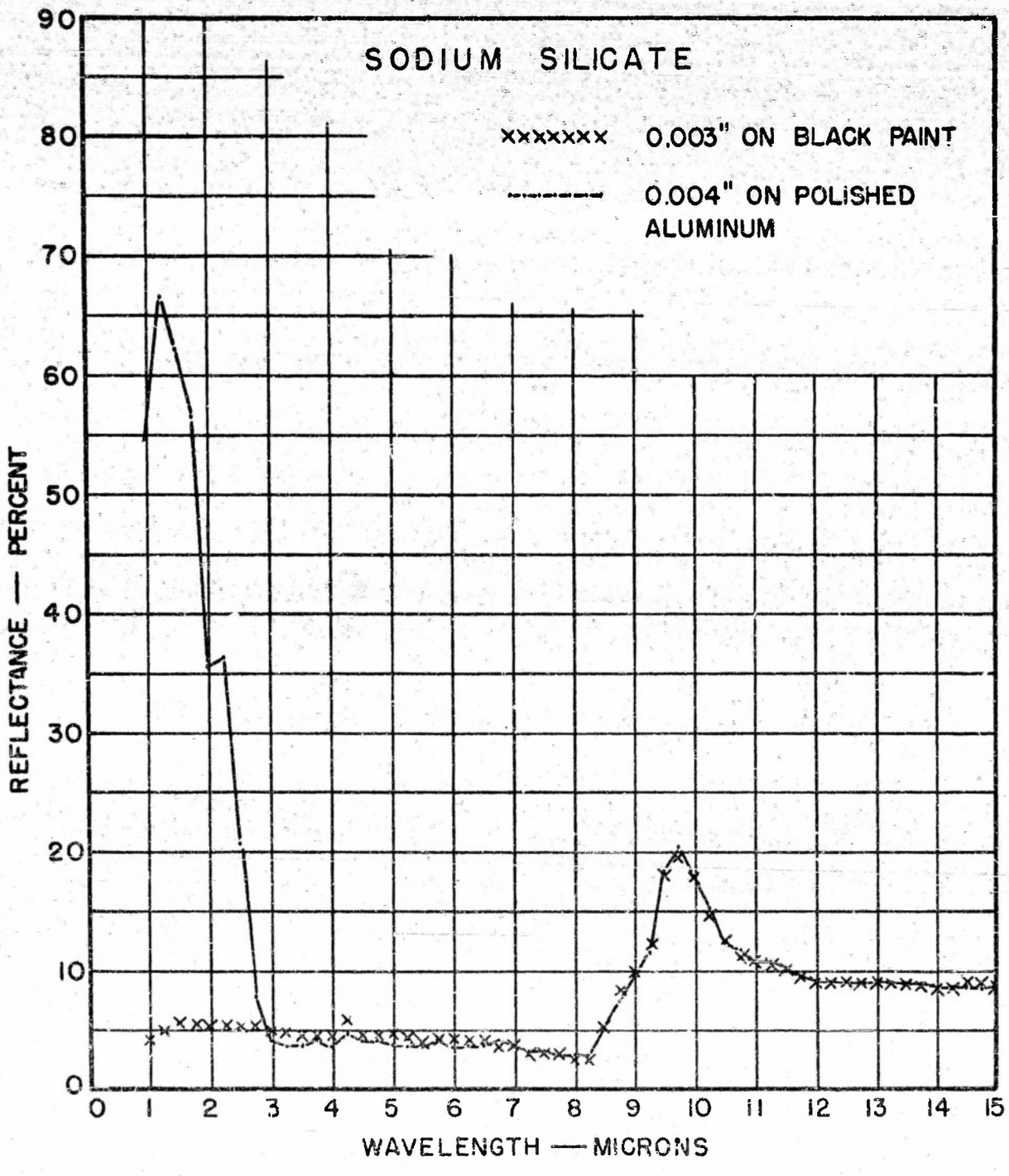
NOMENCLATURE

e_λ = Monochromatic emissivity

r_λ = Monochromatic reflectivity


SODIUM SILICATE
xxxxxxx 0.003" ON BLACK PAINT
0.004" ON POLISHED ALUMINUM
REFLECTANCE — PERCENT
WAVELENGTH — MICRONS
0
10
20
30
40
50
60
70
80
90
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

CODE - REFLECTANCES OF VARIOUS MINERALS

No.	Description	Background[1]
1	Almandite powder, dusted on sodium silicate 0.025" thick	Sodium silicate
2	Almandite powder, dusted on flat black paint	Flat black paint
3	Alundum powder, dusted on sodium silicate 0.015" thick	Sodium silicate
4	Bauxite powder, dusted on sodium silicate, 0.012" thick	Sodium silicate
5	Benitoite powder, dusted on flat black paint	Flat black paint
6	Calcite powder, dusted on sodium silicate 0.016" thick	Sodium silicate
7	Calcite powder, dusted on sodium silicate 0.010" thick (Scalenohedron)	Sodium silicate
8	Calcite powder, dusted on flat black paint	Flat black paint
9	Carbon electrode (powdered), dusted on sodium silicate, 0.016" thick	Sodium silicate
10	Carborundum powder, dusted on flat black paint 0.024" thick	Flat black paint
11	Carborundum powder, dusted on sodium silicate 0.015" thick	Sodium silicate
12	Cement, Portland, dusted on sodium silicate 0.025" thick	Sodium silicate
13	Chripobul powder, dusted on sodium silicate	Sodium silicate
14	Chripobul powder, dusted on flat black paint	Flat black paint
15	Dirt (dark), dusted on sodium silicate	Sodium silicate
16	Dirt (dark), dusted on flat black paint	Flat black paint
17	Dirt (light), dusted on sodium silicate	Sodium silicate
18	Dirt (light), dusted on flat black paint	Flat black paint
19	Fluorite powder, dusted on sodium silicate 0.020" thick	Sodium silicate
20	Fluorite powder, dusted on sodium silicate 0.012" thick	Sodium silicate
21	Kaolin, dusted on sodium silicate 0.006" thick	Sodium silicate

No.	Description	Background[1]
22	Kaolin, dusted on flat black paint 0.009" thick	Flat black paint
23	Magnesite powder, dusted on sodium silicate 0.022" thick	Sodium silicate
24	Magnesite powder, dusted on flat black paint 0.014" thick	Flat black paint
25	Magnesium carbonate (solid), on flat black paint approximately 0.016" thick	Flat black paint
26	Mica, sheet 0.015" thick	Polished aluminum
27	Mica, sheet 0.015" thick	Flat black paint
28	Mica, powder, dusted on clear lacquer 0.004" thick	Clear lacquer
29	Pyrite powder, dusted on sodium silicate	Sodium silicate
30	Pyrite powder, dusted on flat black paint	Flat black paint
31	Quartz powder, dusted on sodium silicate 0.030" thick	Sodium silicate
32	Sand, Monterey (quartz), dusted on sodium silicate	Sodium silicate
33	Sand, Monterey (quartz), dusted on flat black paint	Flat black paint
34	Sulfur powder (raw), dusted on sodium silicate 0.010" thick	Sodium silicate
35	Titanite (in chlorite) powder, dusted on sodium silicate	Sodium silicate
36	Titanite (in chlorite) powder, dusted on flat black paint	Flat black paint
37	Topaz powder, dusted on sodium silicate 0.025" thick	Sodium silicate
38	Tourmaline powder, dusted on sodium silicate	Sodium silicate
39	Tourmaline powder, dusted on flat black paint	Flat black paint
40	Turquois powder, dusted on sodium silicate	Sodium silicate
41	Turquois powder, dusted on flat black paint	Flat black paint

NOTE: (1) The background material is that from which a second reflection would occur if the materials were transmittant.
(2) All values of reflectivity (r) are given as a percentage of 1.

WAVELENGTH Microns	MATERIAL					
	1	2	3	4	5	6
1.0	29.2	23.1	83.3	43.4	34.5	61.0
1.25	16.4	17.9	84.9	44.1	37.1	64.4
1.50	19.4	20.4	85.0	42.0	41.4	58.5
1.75	19.8	20.5	85.1	40.6	43.0	53.0
2.0	20.8	21.5	84.9	32.7	44.6	39.2
2.25	19.2	20.8	85.7	27.2	42.4	37.4
2.50	19.5	23.2	84.3	23.8	45.0	28.1
2.75	15.7	24.8	77.1	11.5	29.7	24.9
3.0	13.2	24.5	56.2	8.6	20.6	17.4
3.25	12.8	28.0	61.0	12.2	26.3	16.1
3.50	12.8	25.2	66.1	14.9	20.3	11.6
3.75	12.9	26.2	76.7	16.4	35.1	16.5
4.0	14.5	26.0	78.8	16.1	38.2	11.2
4.25	15.2	26.2	80.6	16.5	40.3	17.7
4.50	14.3	22.0	77.4	14.9	36.7	16.8
4.75	14.0	22.3	77.2	12.4	31.5	16.2
5.0	14.5	20.3	72.3	10.8	21.8	16.9
5.25	14.1	15.7	74.7	12.0	21.4	16.4
5.50	13.9	13.9	72.7	11.1	20.8	12.8
5.75	13.2	13.3	67.2	11.2	9.9	11.9
6.0	13.1	16.5	58.2	9.5	9.9	10.7
6.25	12.7	15.3	49.0	9.1	12.2	11.1
6.50	14.0	15.5	45.1	10.2	15.5	32.5
6.75	13.7	14.1	38.2	10.3	11.6	28.5
7.0	13.6	13.2	28.2	10.3	9.0	23.6
7.25	12.9	13.2	23.7	9.4	9.1	17.5
7.50	12.4	13.2	17.2	9.9	9.0	16.2
7.75	13.2	12.6	14.1	10.2	8.2	16.8
8.0	12.5	11.6	11.9	9.0	6.6	16.3
8.25	11.6	11.2	9.4	8.5	5.3	15.7
8.50	11.2	10.6	7.4	8.6	5.7	15.1
8.75	11.3	10.6	5.7	8.5	5.8	16.5
9.0	11.2	10.3	5.0	9.1	8.8	17.2
9.25	11.6	10.3	4.9	9.4	13.1	17.2
9.50	14.9	15.1	4.6	10.0	13.9	17.4
9.75	26.6	29.9	4.5	9.5	14.6	16.0
10.0	31.0	32.8	4.5	9.4	10.2	16.4
10.25	31.7	32.5	5.7	9.0	9.4	16.6
10.50	17.1	16.5	7.5	8.7	13.0	16.5
10.75	16.1	15.3	11.2	9.1	16.2	16.9
11.0	27.9	28.8	16.2	9.1	13.8	17.2
11.25	23.4	20.5	23.8	9.1	11.9	17.9
11.50	25.3	25.8	27.2	9.1	11.2	18.2
11.75	20.3	20.0	27.5	8.7	12.2	16.8
12.0	18.9	18.2	27.0	8.7	11.1	17.2
12.25	18.4	17.8	27.4	9.1	9.8	17.7
12.50	17.6	16.5	28.4	8.7	9.4	17.8
12.75	17.5	16.5	29.3	8.7	12.4	17.1
13.0	17.5	15.7	30.1	9.0	15.6	17.4
13.25	16.5	15.8	30.7	8.8	14.9	17.8
13.50	16.3	15.6	31.5	9.4	13.5	17.4
13.75	15.6	15.1	31.7	9.4	12.6	17.8
14.0	15.6	14.8	32.4	9.4	13.2	18.0
14.25	15.2	15.1	33.9	9.4	14.0	16.8
14.50	15.2	15.7	33.9	9.6	14.0	16.9
14.75	14.6	14.7	34.3	9.9	14.3	17.3
15.0	16.2	15.9	34.8	10.4	15.9	16.9

WAVELENGTH Microns	MATERIAL					
	7	8	9	10	11	12
1.0	55.5	43.6	2.6	7.1	10.8	35.1
1.25	59.1	45.0	3.3	7.7	11.9	39.7
1.50	55.0	47.5	3.3	7.8	11.7	44.0
1.75	51.1	48.3	3.7	7.9	11.8	50.0
2.0	41.4	47.7	3.7	7.8	12.0	52.8
2.25	42.5	46.1	4.1	8.2	12.3	57.4
2.50	33.5	44.3	4.1	8.2	13.2	57.1
2.75	26.8	44.6	4.9	8.1	13.1	22.4
3.0	18.3	35.4	5.0	7.8	12.2	20.2
3.25	17.7	36.9	4.6	7.7	12.4	28.7
3.50	13.2	14.8	4.6	7.3	12.3	32.4
3.75	17.1	36.1	4.2	7.4	13.0	39.3
4.0	10.0	19.3	4.6	7.4	13.0	38.5
4.25	16.7	42.0	5.7	8.7	14.1	43.8
4.50	16.6	39.4	4.9	7.3	13.8	42.9
4.75	15.3	41.2	5.0	7.4	13.4	42.7
5.0	15.9	41.5	5.0	7.8	14.0	40.5
5.25	13.5	37.8	5.4	7.8	13.9	34.3
5.50	11.4	20.5	5.8	8.2	14.6	26.4
5.75	10.3	13.2	5.2	8.2	14.2	26.0
6.0	9.0	11.5	6.2	8.2	14.2	23.6
6.25	9.0	11.6	6.1	7.8	14.1	19.7
6.50	25.0	27.6	7.3	7.7	15.7	13.0
6.75	18.9	21.5	6.9	8.2	15.5	13.2
7.0	15.6	19.4	7.7	7.8	14.5	15.2
7.25	14.1	16.5	7.5	7.8	14.8	15.2
7.50	16.5	18.8	7.4	7.4	14.5	19.8
7.75	19.6	20.7	7.4	7.4	14.8	20.1
8.0	18.2	20.6	7.0	7.4	14.5	17.5
8.25	18.9	20.3	6.6	7.4	14.1	14.4
8.50	16.8	18.5	7.0	7.0	13.0	13.9
8.75	17.3	21.2	7.0	7.0	13.1	14.1
9.0	18.1	23.2	7.1	7.0	13.2	14.1
9.25	17.8	22.2	7.1	7.0	12.2	14.8
9.50	17.6	23.1	7.0	6.6	11.4	14.3
9.75	17.2	20.8	7.5	6.2	11.5	14.3
10.0	16.7	22.0	7.7	6.2	11.6	15.6
10.25	16.1	24.2	7.3	6.2	14.5	16.5
10.50	16.3	24.1	7.9	23.5	27.6	16.3
10.75	16.0	25.3	8.6	29.8	32.4	17.1
11.0	16.0	27.2	8.6	35.2	36.4	17.3
11.25	16.8	24.2	9.0	38.4	39.4	17.9
11.50	13.1	16.8	8.7	42.1	42.2	18.3
11.75	15.4	20.2	8.6	43.2	45.7	17.9
12.0	16.5	29.1	8.6	44.2	45.5	17.6
12.25	16.1	28.4	8.6	44.2	45.1	17.8
12.50	16.0	28.0	8.7	40.7	40.2	18.1
12.75	16.4	25.2	8.2	34.7	32.0	17.6
13.0	15.6	27.2	9.0	25.4	28.5	18.2
13.25	15.5	26.2	9.0	22.9	26.8	20.5
13.50	15.7	24.4	9.1	21.4	26.1	18.7
13.75	14.5	21.7	9.4	19.8	24.1	18.2
14.0	11.1	15.8	9.4	17.8	24.0	19.4
14.25	15.4	23.7	9.7	17.7	22.8	20.1
14.50	17.4	29.0	9.9	17.7	23.2	20.5
14.75	15.9	30.0	10.0	17.0	23.5	20.8
15.0	17.8	30.5	10.4	16.9	22.8	21.8

WAVELENGTH Microns	MATERIAL					
	13	14	15	16	17	18
1.0	11.5	18.7	30.1	20.5	32.5	24.6
1.25	14.5	21.4	37.1	25.9	39.9	28.5
1.50	15.3	21.4	38.9	27.0	39.9	29.5
1.75	15.8	23.8	39.1	29.2	39.2	29.5
2.0	14.6	23.6	32.6	28.9	33.6	29.3
2.25	15.0	22.4	32.4	25.5	33.6	26.2
2.50	14.0	22.8	25.5	24.3	26.2	22.9
2.75	9.8	17.9	4.1	5.0	4.1	4.5
3.0	9.0	15.6	4.1	6.3	4.1	5.7
3.25	9.1	16.1	6.5	8.0	5.7	8.1
3.50	9.5	14.3	10.3	8.3	10.2	8.7
3.75	9.9	18.0	15.0	17.5	13.8	16.4
4.0	10.6	19.0	15.6	19.8	16.3	18.6
4.25	10.7	20.5	16.7	21.6	16.7	20.5
4.50	10.5	18.7	12.9	18.7	14.0	16.6
4.75	10.2	18.5	12.2	17.4	12.2	14.7
5.0	10.2	16.6	8.1	12.2	9.8	10.3
5.25	10.8	15.3	6.9	10.7	8.9	9.0
5.50	9.8	15.1	6.5	8.0	7.7	7.4
5.75	10.1	11.9	6.1	5.9	7.4	6.2
6.0	9.6	11.4	4.1	3.8	4.1	4.9
6.25	8.6	9.7	4.0	4.2	3.2	5.0
6.50	10.6	11.8	5.7	6.3	6.1	10.7
6.75	10.2	11.0	4.9	5.9	5.7	6.3
7.0	10.4	11.0	4.1	5.8	4.9	5.7
7.25	10.0	11.3	4.5	5.9	4.5	4.9
7.50	9.5	10.2	4.1	5.8	4.5	5.4
7.75	11.0	11.5	4.9	5.9	5.3	6.2
8.0	9.5	9.8	4.9	6.3	4.9	5.3
8.25	8.9	9.1	6.5	7.9	6.5	7.9
8.50	9.9	9.4	6.5	7.9	5.8	6.5
8.75	10.2	9.8	6.6	7.5	7.4	7.0
9.0	12.0	9.8	6.5	7.9	6.5	7.8
9.25	16.2	13.0	7.4	8.9	8.2	9.1
9.50	18.8	15.1	7.4	8.3	8.5	8.5
9.75	19.2	15.1	7.0	7.9	7.0	8.2
10.0	16.7	14.4	6.2	6.6	6.6	7.4
10.25	16.7	15.3	5.7	6.2	5.7	7.4
10.50	17.8	19.2	5.3	7.0	5.3	7.4
10.75	19.0	20.9	5.3	6.2	4.9	7.4
11.0	21.0	25.3	5.7	7.8	5.3	7.7
11.25	22.5	24.4	5.7	7.9	5.8	7.7
11.50	23.8	21.3	5.7	8.4	5.3	7.4
11.75	22.6	23.8	5.4	8.2	5.7	7.8
12.0	21.0	22.4	5.7	7.0	5.3	7.4
12.25	20.5	21.2	4.9	8.6	4.9	7.7
12.50	24.4	26.4	4.9	7.4	4.9	8.6
12.75	26.1	28.3	5.4	7.4	4.9	7.4
13.0	25.4	26.1	4.9	7.1	4.9	8.2
13.25	24.4	24.0	5.8	8.2	6.5	8.1
13.50	22.6	22.6	5.7	8.3	6.1	8.2
13.75	20.3	19.9	5.7	7.1	5.7	8.2
14.0	21.6	20.6	5.7	8.3	5.7	9.0
14.25	21.7	23.9	5.7	7.8	6.5	8.7
14.50	22.2	24.2	5.7	7.9	7.0	9.5
14.75	23.1	24.7	6.5	9.1	7.0	8.6
15.0	24.7	23.6	7.3	9.5	8.2	10.1

WAVELENGTH Microns	MATERIAL					
	19	20	21	22	23	24
1.0	55.0	56.2	57.3	64.5	61.0	40.5
1.25	59.7	59.7	64.3	64.2	61.0	40.1
1.50	50.0	59.0	62.9	66.5	49.2	39.9
1.75	45.3	56.0	61.7	58.0	40.3	37.3
2.0	29.0	46.3	57.0	51.6	28.9	37.5
2.25	31.5	45.3	40.6	35.1	25.4	34.6
2.50	23.4	38.3	23.4	22.1	20.5	33.6
2.75	16.2	30.7	5.4	8.7	9.1	21.1
3.0	10.3	14.1	5.0	10.2	6.6	10.7
3.25	10.5	14.3	7.8	13.9	6.6	11.0
3.50	10.4	13.9	19.2	17.2	5.7	12.3
3.75	10.2	15.6	34.6	21.9	5.7	13.8
4.0	10.3	17.2	43.2	21.1	7.4	19.2
4.25	11.8	18.2	44.1	21.0	9.0	21.3
4.50	11.0	16.8	40.8	17.7	7.5	17.5
4.75	10.7	17.2	33.7	14.8	7.9	18.9
5.0	10.0	18.2	28.1	12.3	8.2	17.2
5.25	10.6	18.0	12.2	10.2	8.2	12.4
5.50	10.8	17.7	7.9	9.4	7.4	7.5
5.75	10.4	17.5	13.5	9.2	8.2	6.5
6.0	10.4	15.6	9.4	8.3	7.9	9.1
6.25	10.4	15.6	12.2	8.1	9.5	16.5
6.50	11.1	17.6	15.2	9.9	10.7	12.6
6.75	10.7	17.1	13.2	9.4	9.9	10.9
7.0	10.3	16.7	11.6	8.6	9.5	10.7
7.25	10.4	16.9	10.6	8.6	9.5	12.4
7.50	10.7	17.5	9.5	7.8	9.4	14.6
7.75	10.6	18.0	7.8	8.5	9.4	14.0
8.0	10.4	16.5	4.5	7.7	7.8	11.5
8.25	10.3	16.4	3.3	7.0	7.7	12.2
8.50	10.7	15.2	3.7	7.4	8.3	12.9
8.75	10.5	14.8	8.3	11.6	10.4	11.6
9.0	10.3	14.1	7.0	9.5	11.5	11.6
9.25	10.8	14.5	31.9	27.0	13.5	11.4
9.50	12.0	15.2	47.7	33.4	16.7	12.3
9.75	12.4	15.3	25.8	19.5	17.2	12.3
10.0	11.6	14.3	21.9	18.0	16.4	11.2
10.25	11.5	14.6	9.8	11.8	14.2	10.7
10.50	10.6	14.6	6.1	10.8	14.0	10.7
10.75	10.4	13.9	9.4	12.8	12.3	11.2
11.0	10.4	14.2	15.4	15.8	12.7	13.9
11.25	10.2	14.2	[illegible].8	12.8	13.1	9.4
11.50	10.3	14.3	8.6	11.8	13.1	11.5
11.75	10.4	14.0	7.8	11.4	13.0	11.5
12.0	9.4	13.9	6.6	11.1	12.5	10.5
12.25	10.4	13.5	6.1	11.6	12.3	10.8
12.50	10.0	13.2	5.8	11.2	11.5	10.0
12.75	9.4	12.5	6.2	11.4	12.3	10.2
13.0	9.9	12.4	5.8	11.0	12.2	9.6
13.25	9.5	11.9	5.4	11.1	12.6	8.2
13.50	9.9	12.1	5.0	10.7	12.9	9.4
13.75	9.6	11.6	5.0	10.7	12.9	9.8
14.0	9.9	11.1	4.9	10.7	13.1	10.7
14.25	10.0	11.5	5.3	10.7	13.2	10.3
14.50	10.8	11.4	5.3	11.8	13.8	11.5
14.75	10.0	11.5	5.3	11.6	14.0	9.5
15.0	11.9	11.8	5.4	12.6	13.7	11.8

WAVELENGTH Microns	MATERIAL					
	25	26	27	28	29	30
1.0	84.5	67.9	13.5	52.5	11.8	12.2
1.25	83.2	72.0	17.9	61.8	16.5	13.9
1.50	76.7	75.5	18.3	65.0	19.0	18.1
1.75	73.8	79.8	19.6	37.3	19.0	19.5
2.0	61.2	80.3	20.0	69.5	19.8	20.2
2.25	55.6	75.5	20.7	64.6	19.1	19.5
2.50	40.8	75.4	18.5	62.1	19.2	19.9
2.75	13.8	67.7	18.4	56.6	13.1	20.6
3.0	6.7	74.7	19.7	34.8	11.3	19.1
3.25	8.4	83.9	21.4	49.1	11.5	19.9
3.50	8.9	83.2	15.8	30.3	12.1	19.0
3.75	10.4	84.9	16.6	57.6	13.8	20.5
4.0	10.9	87.5	15.5	62.2	14.7	21.3
4.25	14.4	86.5	22.9	65.6	15.8	21.8
4.50	9.9	84.9	15.0	62.5	14.6	22.1
4.75	10.3	77.8	17.4	60.2	15.4	21.5
5.0	9.5	75.8	19.5	63.5	15.2	22.1
5.25	9.0	69.9	19.2	61.5	15.5	22.6
5.50	9.1	45.2	15.6	50.4	14.7	21.4
5.75	9.1	45.1	12.3	31.8	13.8	20.0
6.0	10.5	44.4	10.4	25.8	12.7	20.5
6.25	12.5	57.4	11.2	37.6	12.7	20.4
6.50	15.4	60.7	15.9	49.2	14.2	21.8
6.75	14.5	56.6	15.6	35.0	14.0	19.7
7.0	15.0	47.7	11.2	31.8	13.5	19.3
7.25	15.4	42.8	11.0	28.8	13.9	19.6
7.50	15.5	39.7	10.9	27.9	14.2	21.1
7.75	16.5	35.0	10.3	21.7	15.0	21.4
8.0	15.3	27.7	8.2	20.8	13.0	20.5
8.25	14.4	21.8	7.4	23.1	12.6	19.3
8.50	14.4	16.2	7.9	21.7	11.7	18.5
8.75	14.4	23.2	18.8	26.2	12.6	18.4
9.0	15.3	46.7	44.0	34.2	12.9	18.4
9.25	15.3	52.5	50.0	36.7	13.9	19.0
9.50	14.5	51.8	48.2	35.0	15.9	18.7
9.75	16.5	57.9	51.0	38.7	16.7	18.7
10.0	16.7	47.0	40.1	31.9	16.5	19.6
10.25	17.1	41.3	31.6	27.9	15.4	19.7
10.50	17.4	31.9	21.9	23.7	14.8	20.7
10.75	18.1	27.9	18.8	20.8	14.9	21.1
11.0	18.4	27.7	19.4	21.3	14.4	21.3
11.25	20.6	27.0	16.6	21.9	14.3	21.4
11.50	21.5	26.3	15.9	22.8	15.0	20.3
11.75	21.1	25.6	14.9	23.1	14.7	20.5
12.0	21.1	23.9	13.5	22.5	14.3	21.1
12.25	23.0	23.7	12.5	23.1	13.6	21.1
12.50	22.9	23.0	11.4	22.4	13.8	20.4
12.75	22.8	22.0	10.8	22.3	14.2	19.6
13.0	23.5	22.5	10.1	21.0	14.7	19.7
13.25	22.9	22.3	14.3	18.3	14.4	19.7
13.50	23.5	23.2	15.3	19.0	14.5	20.1
13.75	23.5	22.6	15.6	19.4	14.0	20.5
14.0	23.0	22.5	15.4	19.6	15.2	18.7
14.25	24.2	22.9	15.1	19.8	14.8	20.6
14.50	25.9	22.9	15.1	20.2	15.4	20.7
14.75	25.3	23.4	14.7	20.0	13.9	18.5
15.0	26.0	27.1	16.0	22.4	15.4	20.0

WAVELENGTH Microns	MATERIAL					
	31	32	33	34	35	36
1.0	62.6	46.7	15.7	60.0	15.8	14.5
1.25	65.3	52.5	15.2	66.5	18.6	18.8
1.50	61.2	43.9	16.7	63.5	21.4	22.5
1.75	53.7	36.6	17.1	59.1	25.7	24.9
2.0	39.4	26.2	17.2	53.6	25.4	24.5
2.25	35.0	25.6	16.7	53.9	22.4	23.0
2.50	26.9	20.3	16.7	51.0	22.6	23.4
2.75	20.3	9.8	12.4	45.0	12.3	11.2
3.0	12.4	9.1	11.1	31.5	9.2	8.7
3.25	11.9	10.7	14.4	33.3	12.7	14.3
3.50	11.4	12.2	14.6	37.0	12.9	12.0
3.75	12.2	12.3	17.3	40.1	15.8	19.8
4.0	12.4	12.7	17.2	40.2	16.4	21.0
4.25	13.1	12.7	17.3	40.5	17.6	22.7
4.50	12.3	10.3	14.6	41.6	15.4	19.3
4.75	11.4	9.8	13.4	40.6	14.4	17.8
5.0	11.7	8.2	10.6	41.3	13.2	15.8
5.25	11.8	7.8	10.6	40.9	13.4	15.7
5.50	11.5	7.3	10.6	40.2	12.0	13.7
5.75	11.0	7.8	9.4	39.8	10.4	10.3
6.0	11.2	6.6	9.0	36.5	10.2	10.3
6.25	12.0	5.7	9.1	37.4	9.8	10.4
6.50	12.4	7.5	9.9	39.8	12.0	13.1
6.75	12.0	7.4	9.9	39.8	10.6	12.0
7.0	11.9	7.4	10.2	39.3	10.7	11.1
7.25	12.4	6.9	10.6	39.3	10.0	10.7
7.50	12.7	6.9	10.6	38.6	11.0	10.6
7.75	14.3	8.2	10.6	38.0	10.5	11.4
8.0	19.3	11.0	14.9	36.8	8.3	9.3
8.25	20.7	20.7	23.9	35.7	7.4	8.6
8.50	22.2	23.0	25.4	34.2	7.7	7.5
8.75	26.6	23.2	25.3	34.4	7.8	7.4
9.0	28.8	24.4	25.4	33.8	9.3	7.9
9.25	24.8	24.0	24.8	34.4	12.0	10.3
9.50	22.8	18.8	17.9	33.2	15.8	11.5
9.75	20.8	15.7	16.8	33.7	21.0	14.9
10.0	20.0	14.6	16.0	34.6	19.0	14.6
10.25	19.1	12.7	15.2	36.0	16.2	13.3
10.50	18.5	12.2	13.9	35.1	15.7	12.7
10.75	18.0	11.4	14.3	32.3	13.8	12.0
11.0	17.9	11.5	14.4	33.2	14.0	11.5
11.25	17.9	10.7	14.0	31.9	11.6	14.7
11.50	17.7	10.6	13.8	29.6	11.7	10.6
11.75	17.6	10.5	13.4	24.9	11.9	10.3
12.0	17.7	9.8	13.0	25.0	10.7	11.0
12.25	17.6	9.1	13.1	29.6	11.2	10.7
12.50	17.5	11.4	14.7	31.9	10.4	9.5
12.75	18.0	12.2	15.5	32.9	11.8	10.3
13.0	17.9	11.4	15.6	32.4	11.9	11.6
13.25	18.5	11.5	15.2	33.4	12.0	12.0
13.50	18.4	11.4	14.8	33.3	12.5	11.1
13.75	18.9	10.6	15.5	32.3	12.0	11.9
14.0	18.9	11.8	15.2	31.4	12.4	11.6
14.25	19.2	11.0	14.7	31.2	12.2	12.6
14.50	19.2	11.6	15.2	31.4	13.0	12.3
14.75	18.9	11.6	15.7	31.2	12.6	12.3
15.0	19.4	13.2	16.1	31.6	15.2	14.8

WAVELENGTH	MATERIAL				
Microns	37	38	39	40	41
1.0	52.8	10.3	5.8	43.1	13.6
1.25	59.0	10.3	5.8	50.2	15.2
1.50	55.1	14.1	7.5	44.7	14.3
1.75	52.0	19.9	10.0	42.4	13.4
2.0	40.9	21.0	12.4	27.9	10.7
2.25	40.6	22.1	13.2	27.9	10.6
2.50	31.8	20.1	14.2	17.8	8.1
2.75	24.1	11.4	8.6	3.7	3.3
3.0	16.1	16.6	12.4	3.7	3.3
3.25	16.6	20.2	14.0	4.1	3.7
3.50	16.9	16.6	11.4	4.9	4.1
3.75	18.3	15.1	11.6	6.2	5.4
4.0	19.5	14.6	13.8	6.5	6.1
4.25	19.5	17.5	13.3	8.2	7.8
4.50	18.7	13.2	11.3	6.1	5.7
4.75	18.3	13.1	10.9	4.9	5.4
5.0	19.5	11.5	11.9	4.9	4.5
5.25	12.9	12.2	10.4	4.9	4.5
5.50	11.1	11.5	9.5	4.1	4.1
5.75	12.4	9.5	6.9	4.1	4.1
6.0	11.9	8.9	6.6	3.3	3.7
6.25	11.6	7.0	5.7	2.5	3.4
6.50	12.0	7.3	7.3	4.1	4.9
6.75	11.2	5.7	6.2	4.1	4.5
7.0	10.3	4.5	9.5	4.1	4.1
7.25	10.3	5.3	5.9	3.3	4.1
7.50	9.0	4.9	5.8	3.3	4.1
7.75	8.7	7.9	7.0	4.1	4.9
8.0	7.4	7.0	7.8	4.1	4.9
8.25	7.0	5.8	6.7	6.5	6.5
8.50	6.9	4.6	6.2	7.4	7.3
8.75	7.4	3.7	4.1	9.8	10.2
9.0	8.2	6.1	6.4	9.8	10.6
9.25	9.0	9.0	8.3	9.4	9.8
9.50	13.1	7.9	9.1	8.2	7.7
9.75	16.7	9.5	9.8	7.7	6.9
10.0	20.2	9.5	10.3	7.4	7.3
10.25	21.7	10.7	12.8	6.6	6.9
10.50	24.5	9.3	11.5	5.7	6.5
10.75	21.7	8.2	10.7	5.3	5.7
11.0	21.3	8.0	9.3	5.8	5.7
11.25	22.3	7.5	9.5	5.4	5.7
11.50	22.5	7.4	8.7	4.9	5.7
11.75	18.2	7.0	9.0	4.5	5.7
12.0	13.2	6.6	8.3	4.1	5.7
12.25	12.3	6.5	8.1	4.1	5.7
12.50	11.6	6.6	7.0	5.3	5.7
12.75	11.1	7.5	7.8	4.9	6.1
13.0	9.8	7.1	9.5	5.8	5.7
13.25	10.2	6.6	9.1	5.3	6.5
13.50	9.9	5.8	6.8	5.8	6.5
13.75	9.0	3.3	7.3	4.9	5.7
14.0	8.6	5.0	9.6	5.3	6.6
14.25	9.0	4.1	9.9	5.3	6.1
14.50	9.5	4.9	9.1	6.6	7.4
14.75	9.9	3.7	8.2	6.6	7.7
15.0	10.0	4.1	9.5	7.7	8.6